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Introduction

Since the inception of activity in space feeding, the Food Division of the U.S. Army Natick Laboratories, formerly the Armed Forces Food and Container Institute, has provided outstanding research and development support to the NASA. The Food Division personnel have, within the past year, given two presentations (1) and (2) now in press, describing the development of many of the Project Mercury and Gemini menu items. The NASA design criteria and philosophy which guided these developments in space feeding were recently reported (3). Underlying many of the developments are the research undertaken by the U.S. Army for the U.S. Air Force (4) and the recommendations (5) and evaluations (6) and (7) of early workers in this field.

The purpose of this paper is to describe the evolution of the feeding concepts utilized in Project Mercury missions and envisioned for Project Gemini and early Apollo missions.

Project Mercury Concept

Although sustenance is an important part of the life support requirements in spacecraft systems, the short duration Project Mercury flights – with the exception of Astronaut Cooper's MA-9 flight – did not make food mandatory. However, experience with the handling of food and food containers and information on the physiological functioning of the gastro-intestinal tract during periods of weightlessness were needed in anticipation of missions of longer duration, including MA-9, where sustenance would become an important factor.

The foods used in the early orbital Project Mercury flights are shown in figure 1. These foods consisted of pureed meat, vegetables, and fruits, in collapsible metal tubes, and malted milk tablets and bite-sized cubes. A resume of all the foods eaten during the Project Mercury flights

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is given in figure 2. It should be noted that dehydrated foods were included in the MA-9 flight. The short duration of the Project Mercury flights precluded the need for specific food storage areas and food was principally carried in the astronaut's ditty bag.

Project Gemini Concept

The two-astronaut Project Gemini program includes flights of up to 14 days duration. To assure system integration in time for the actual flights, specific criteria for food and its space, weight, and power requirements were established (3).

Briefly, the Project Gemini food concept provides 2,500 kilocalories per man per day, and, because of waste management problems, is of a low residue nature. The present concept consists of a 4-day cycle of four meals per day with a caloric distribution of 17 percent in protein, 32 percent in fats, and 51 percent in carbohydrates. A typical Project Gemini 1-day menu is shown in figure 3. Each man-day supply weighs approximately 1.3 pounds per man per day and occupies approximately 110 cubic inches of storage space. The food and packaging are required to meet flight qualification requirements, most of which are shown in Table I.

Table I. - FOOD AND FOOD PACKAGING ENVIRONMENTAL TESTING REQUIREMENTS

Temperature	+20° F +135° F
Pressure	19.7 psia (70° F) 1×10^{-8} psia (110° F)
Relative Humidity	98% in air at 14.7 psia, 100°F
Atmosphere	100% oxygen
Acoustic Noise	Overall of 135 db, 37.5 to 4800 cps
Acceleration (Launch)	longitudinal spacecraft axis: 1g to 7.25g Linearly with time over 326 seconds.

The lightweight dehydrated foods and compressed energy-dense bite-sized foods were found best suited to fulfilling the criteria and flight qualification requirements. The inclusion of compressed bite-sized pieces permits the menu energy balance to be more readily accomplished and decreases the number of meal items requiring rehydration, thus decreasing the time required for meal preparation. The weight and volume economies that are realized by using Project Gemini type foods in comparison with the Project Mercury concept, expanded to meet the caloric requirements specified for Gemini, are shown in figure 4.

The Project Gemini feeding concept provides fuel-cell water for drinking and food rehydration. Water temperature in the spacecraft reservoir will be between 80° F. and 100° F. No power is allotted for low-temperature food storage or for hot food preparation. The food storage area, providing approximately 3,000 cubic inches, is shown in figure 5. The shape of the container demonstrates the space limitations associated with a compact spacecraft. The food storage area also serves for the storage of waste as the flight progresses and the food is removed.

Packaging Developments

A number of flexible films for packaging were evaluated in 1960 for potential use under space-flight conditions (8) and other research was undertaken for NASA by both the U.S. Army Natick Laboratories and the Whirlpool Corporation in order to develop a suitable flexible film. Presently a four-ply laminate is being utilized. It consists of an inner and outer layer of polyethylene and middle layers of nylon and aclar. Theoretically, a laminate superior to the aforementioned is envisioned. However, several technical difficulties associated with laminating need to be resolved and work is continuing in this area.

Feeder and Dispenser Design and Interface

In essence, two distinct feeder and dispenser designs were developed almost simultaneously and then merged to provide the best of each concept. Subsequent changes were made to meet interface problems as they arose.

Figure 6 shows the evolution of the feeder design. The principal changes were affected by whether or not the food was molded and by water rehydration interface problems. Figure 7 shows an early concept, which utilized a solid plastic ring-type orifice, as both a water nozzle interface as well as the feeding port. Upon evaluation, this concept was eliminated. Figure 8 shows a similar early concept having a dual-purpose, but nonrigid, port. This type was evaluated during the last Mercury flight. Leakage at the feeder-water dispenser interface occurred during the inflight evaluation and this has led to the present feeder concept (fig. 9) with two ports. One port accepts a water probe for rehydration only, and a separate feeding port is provided at the opposite end which can be closed and opened as needed. The feeding port also serves as the opening through which a germicide tablet is inserted after the pilots have eaten to prevent putrefaction of the unused food.

The use of foods molded in bars to conform with the shape of the feeders is mandatory since it reduces the number of uneven surfaces which can be subjected to abrasion and consequent loss of vacuum and transfer of moisture. In addition, the flat surfaces permit the assembly of the food servings into man-meals or man-day packages in a minimum of space.

The evolution of the dispensers for bite-size pieces is shown in figure 10. The earliest dispenser, which was rigid and provided optimum protection against crushing, was considered too heavy and bulky from a packaging point of view. Subsequent dispensers of lighter weight and containing pull-tapes to facilitate removal of the pieces were used, but such tapes and other attachments were found to float around undesirably and were difficult to control in zero g. The current concept requires manipulating the individual bite-size piece out of the dispenser after it has been cut open along the side.

Concurrent with these packaging changes, increased emphasis was placed on food compression and edible coatings to prevent the crumbling which was a problem in some of the Mercury flights.

The present feeder and dispenser concept is scheduled to be evaluated during short periods of zero g as obtained by aircraft in parabolic flights. The results of these short duration tests and the astronaut evaluation of the complete feeding system during the early Project Gemini flights will provide the operational data needed to definitize a feeding system applicable not only to Project Gemini flights but later missions of similar duration.

Summary

Progress leading to a relization of a feeding system for Project Gemini has been described and represents an integration of selected food and packaging developments to meet the nutritional requirements of the astronaut as adequately as possible, and to maintain the space, weight, and power limitations directly related to the nature of this aerospace vehicle and its mission. The Project Gemini feeding system is designed to feed two men for a period of up to 14 days. It consists of a 4-day cycle menu of freeze dehydrated and otherwise dried food items along with bite-size compressed foods, providing 2,500 kilocalories per man per day. All dehydrated foods can be reconstituted with the cabin-temperature fuel-cell water. A man-day of food requires 110 cubic inches of space and weighs approximately 1.3 pounds. The packaging material of the bite-size dispenser and feeder is a flexible film laminate. The current feeder design has, as an integral part, a one-way rehydration port to receive a pistol-like water injecting probe and a separate feeding port at the opposite end of the pouch.

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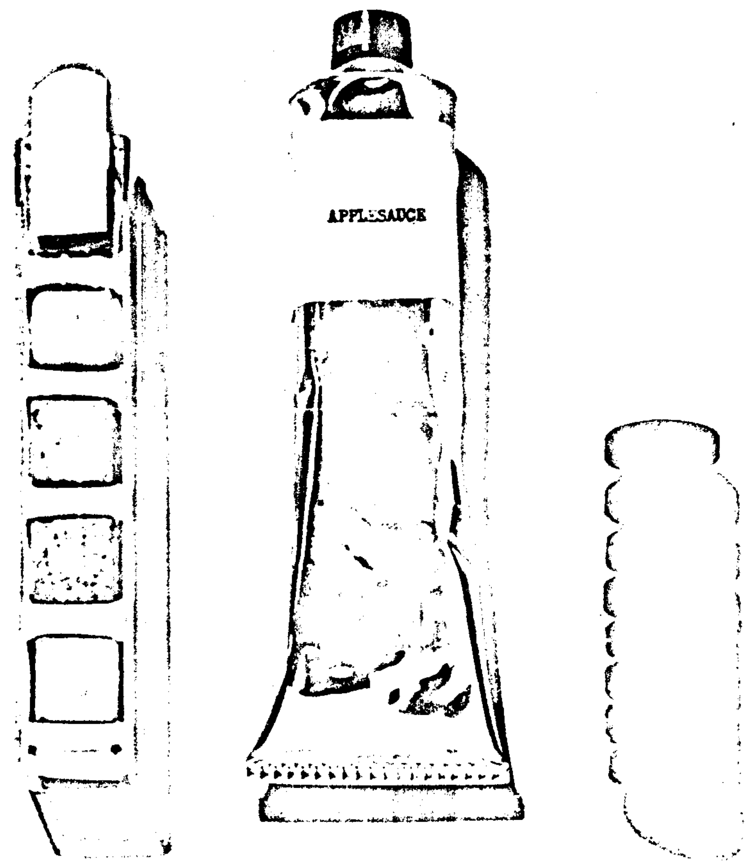

FIGURE 1

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FOOD EATEN - MERCURY SPACECRAFT FLIGHTS

FLIGHT	DATE	ASTRONAUT	DURATION	FOOD EATEN
SUB-ORBITAL, MR-3	MAY 5, 1961	SHEPARD	15 MIN, 22 SEC	NO FOOD ABOARD
SUB-ORBITAL, MR-4	JULY 21, 1961	GRISSOM	15 MIN, 37 SEC	NO FOOD ABOARD
ORBITAL, MA-6	FEB 20, 1962	GLENN	5 HOURS 5 MIN, 10 SEC	PUREED APPLESAUCE, TUBED
ORBITAL, MA-7	MAY 24,1962	CARPENTER	4 HOURS 55 MIN, 36 SEC	CUBES, HIGH CALORIE BLEND
ORBITAL, MA-8	OCT. 3, 1962	SCHIRRA	9 HOURS, 23 MIN, 6 SEC	PUREED PEACHES, BEEF & VEGETABLES, TUBED
ORBITAL, MA-9	MAY 15 & 16, 1963	COOPER	34 HOURS, 31 MIN	REHYDRATABLE FOODS, BITE SIZE READY-TO-EAT FOODS

FIGURE 2

NASA-S-64-2289

PROPOSED PROJECT GEMINI MENU

DAYS 1-5-9-13

MEAL A	MEAL B
SUGAR FROSTED FLAKES	TUNA SALAD
SAUSAGE PATTIES	CHEESE SANDWICHES
TOAST SQUARES	APRICOT PUDDING
ORANGE-GRAPEFRUIT JUICE	GRAPE JUICE

MEAL C	MEAL D
BEEF POT ROAST	POTATO SOUP
CARROTS IN CREAM SAUCE	CHICKEN BITS
TOASTED BREAD CUBES	TOAST SQUARES
PINEAPPLE CUBES	APPLESAUCE
TEA	BROWNIES
	GRAPEFRUIT JUICE

FIGURE 3

NASA-S-64-2440

FOOD WEIGHT AND VOLUME COMPARISON IN PROJECT MERCURY TO PROJECT GEMINI

TO PROVIDE 2500 CALORIES

	MERCURY	GEMINI
• FOODS:	12 TUBES PUREED FOODS	8 BAGS REHYDRATABLE FOODS
	6 ROLL MALTED MILK TABLETS	10 DISPENSING WRAPS OF BITE SIZE READY-TO-EAT FOODS
• WEIGHT:	4.4 POUNDS	1.3 POUNDS
• VOLUME:	191 CUBIC INCHES	110 CUBIC INCHES

FIGURE 4

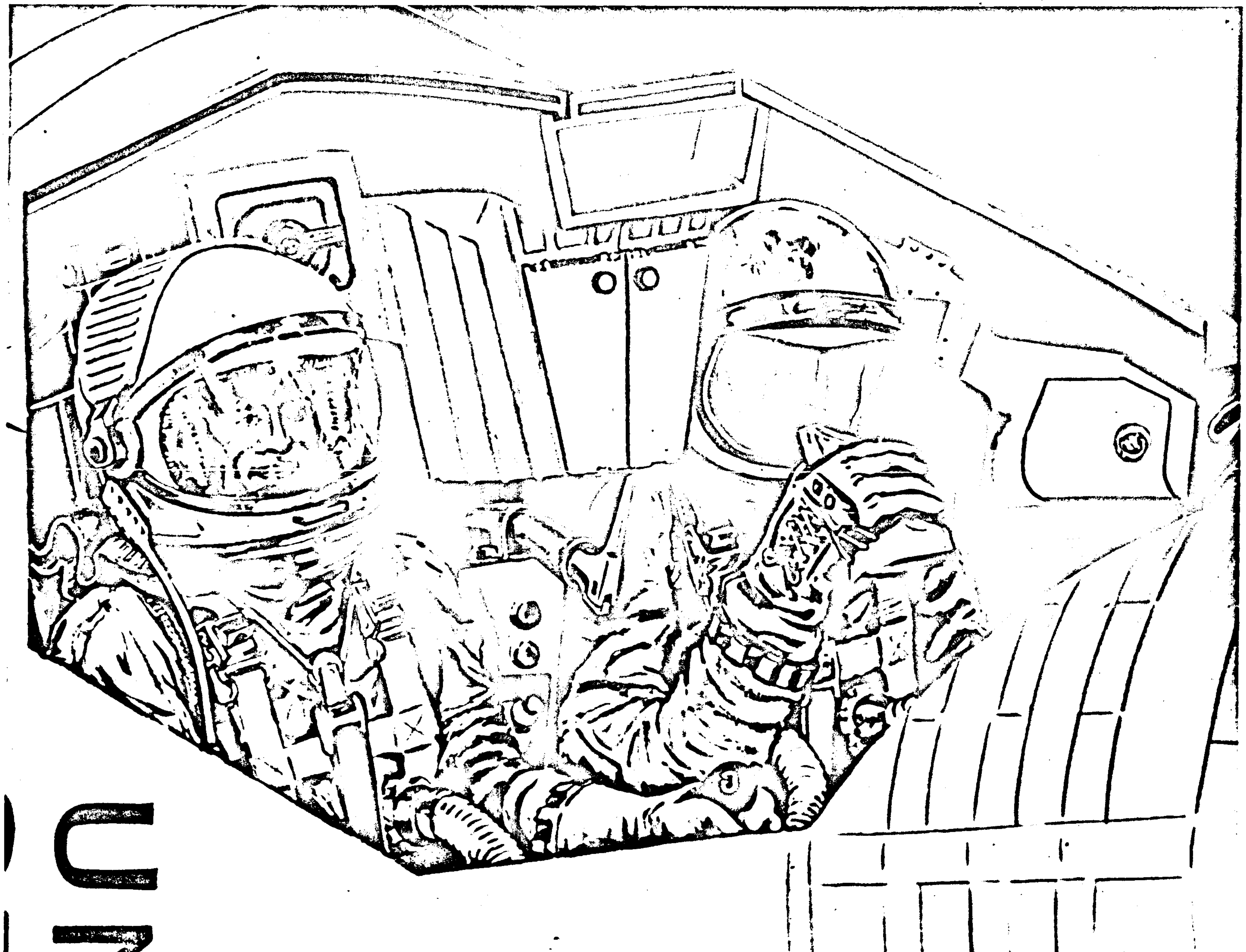

FIGURE 5

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FIGURE 6

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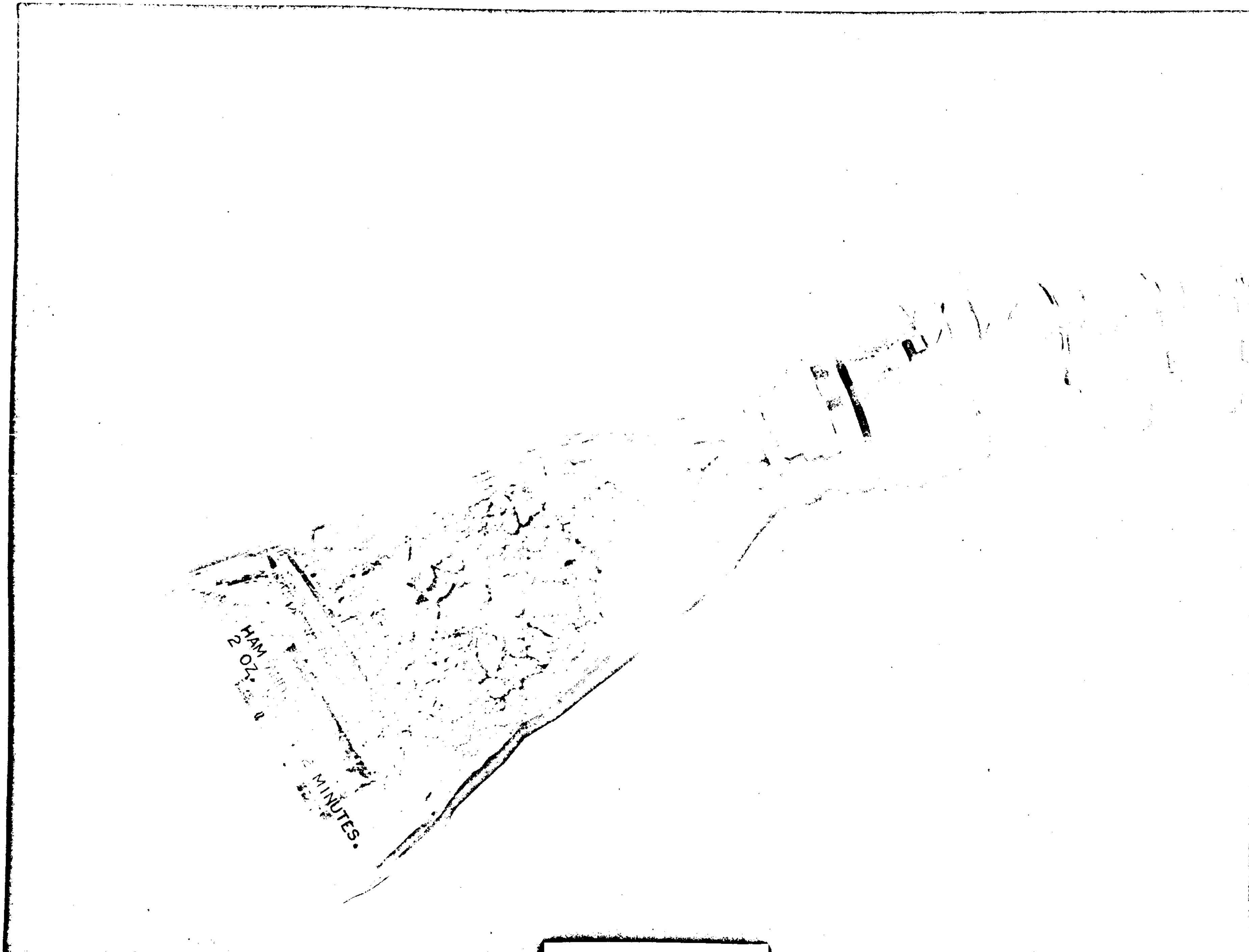

FIGURE 7

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REHYDRATION OF GRAPE JUICE

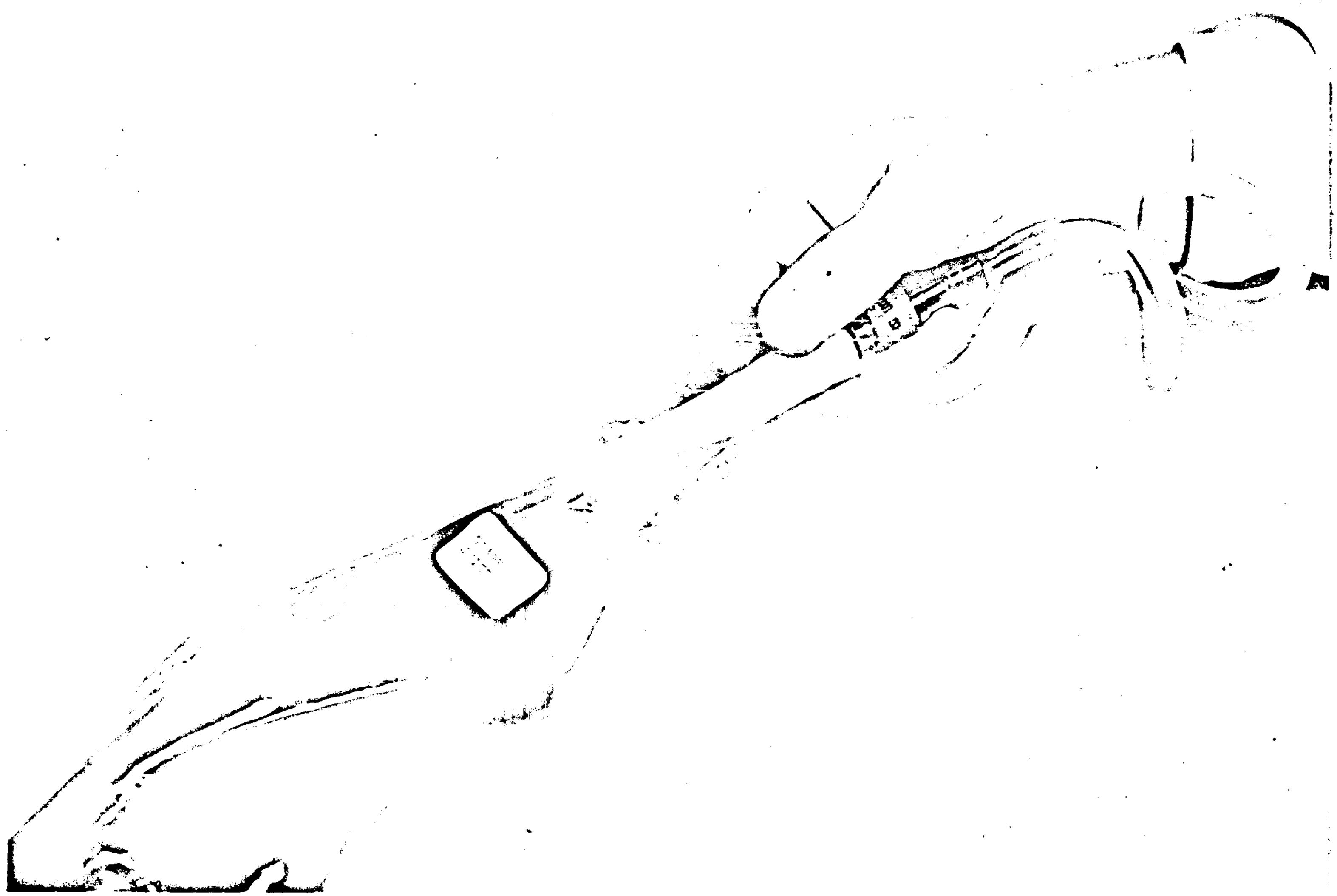

FIGURE 8

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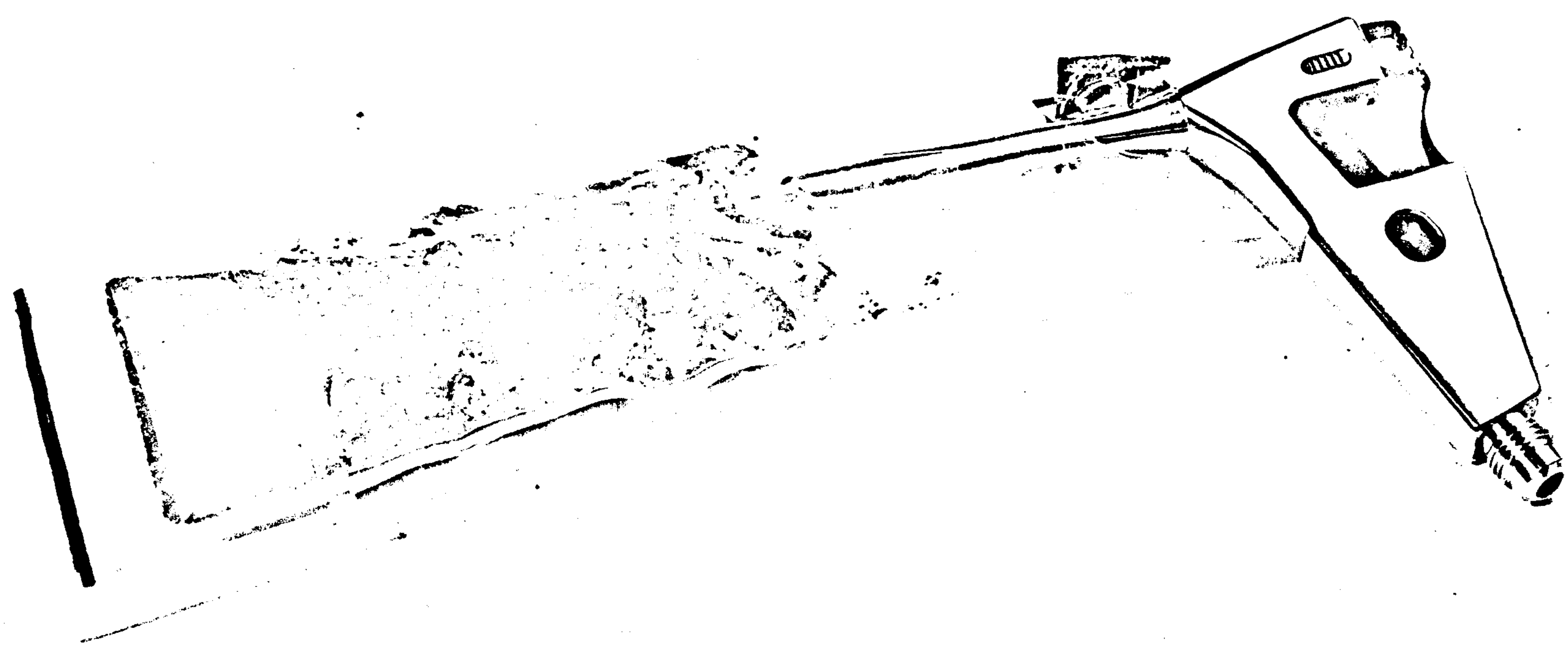

FIGURE 9

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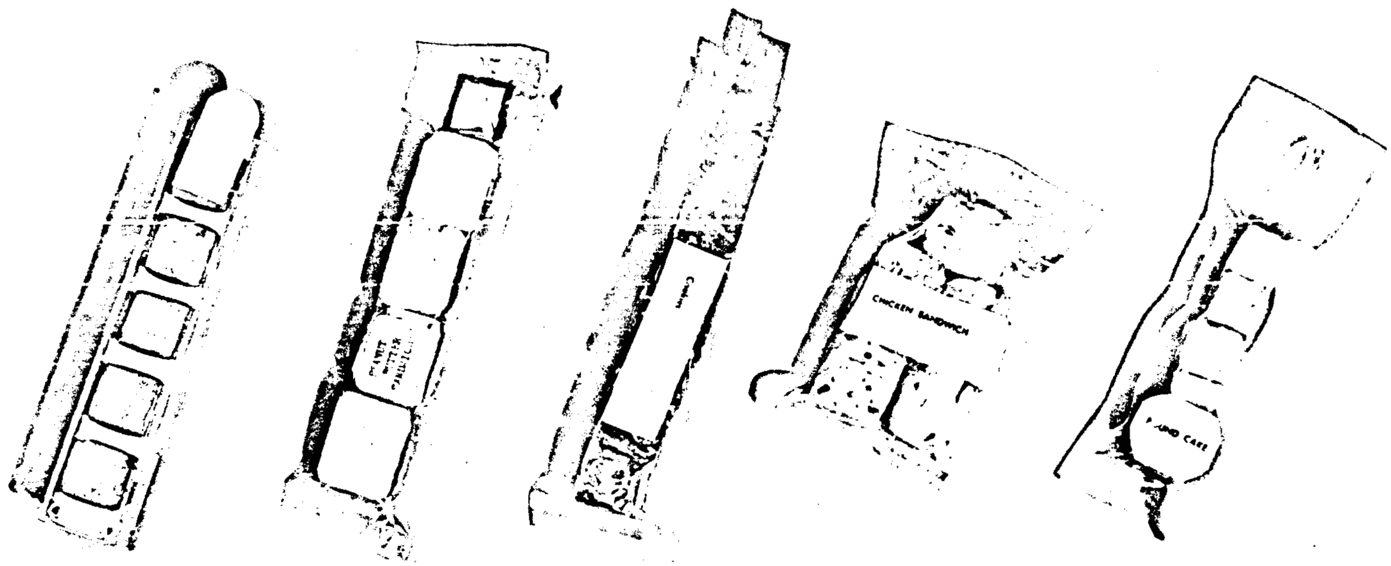

FIGURE 10